



**Do we live in the
Best
of all
Worlds?**

The fine tuning of the constants of Nature

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The Best of all Worlds ?

G.W. Leibniz 1710: **Théodicée**

1. Part § 8: **Unify and Harmonise**
science, metaphysics and theology:

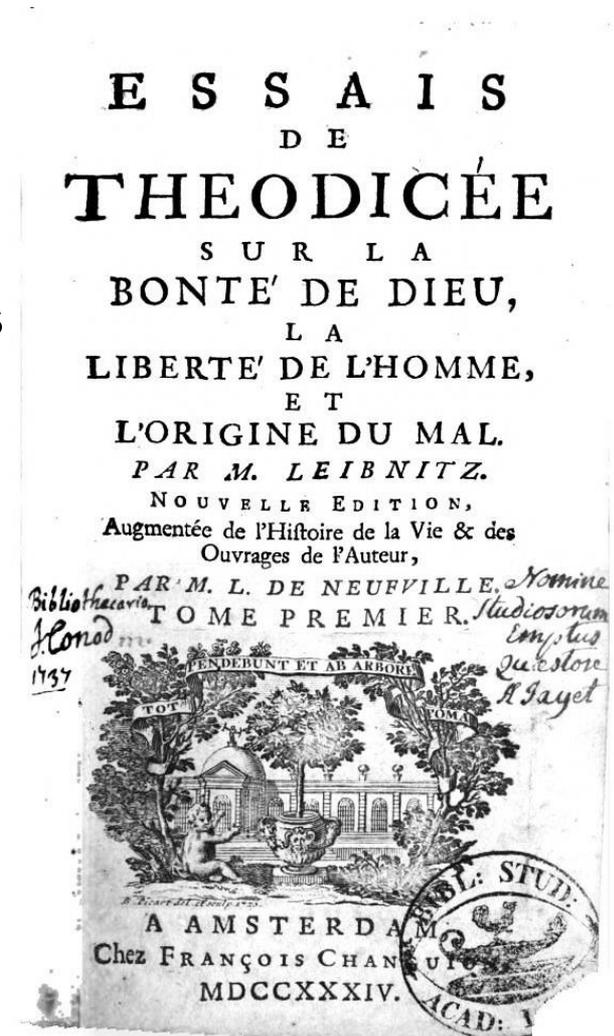
„this supreme wisdom, united to a goodness that is
no less infinite, **cannot but have chosen the best.**

... if there were not **the best among all possible
worlds**, God would not have produced any...

... there is an **infinitude of possible worlds**
among which **God must have chosen the best**,
since he does nothing without acting in
accordance with supreme reason...“

Gottfried Wilhelm Leibniz: Essais de théodicée sur la bonté de Dieu,
la liberté de l'homme, et l'origine du mal. Mortier, Amsterdam 1710.

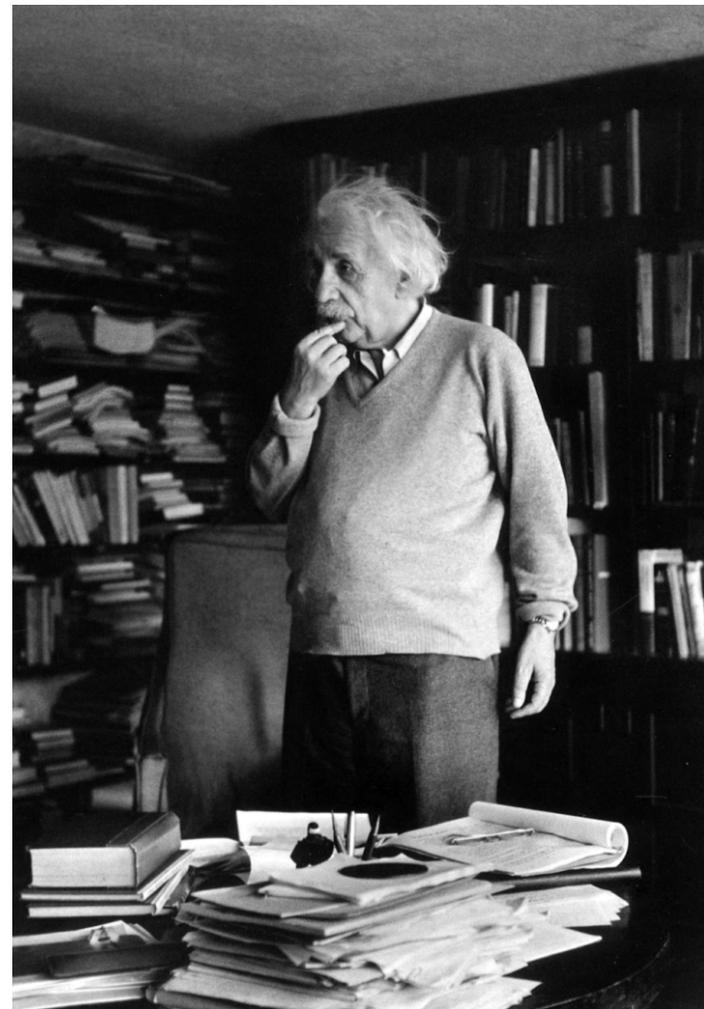
Essays on the Goodness of God, the Freedom of Man and the Origin of
Evil. Translated by E.M. Huggard from C.J. Gerhardt's [Edition](#) of the
Collected Philosophical Works, 1875-90.



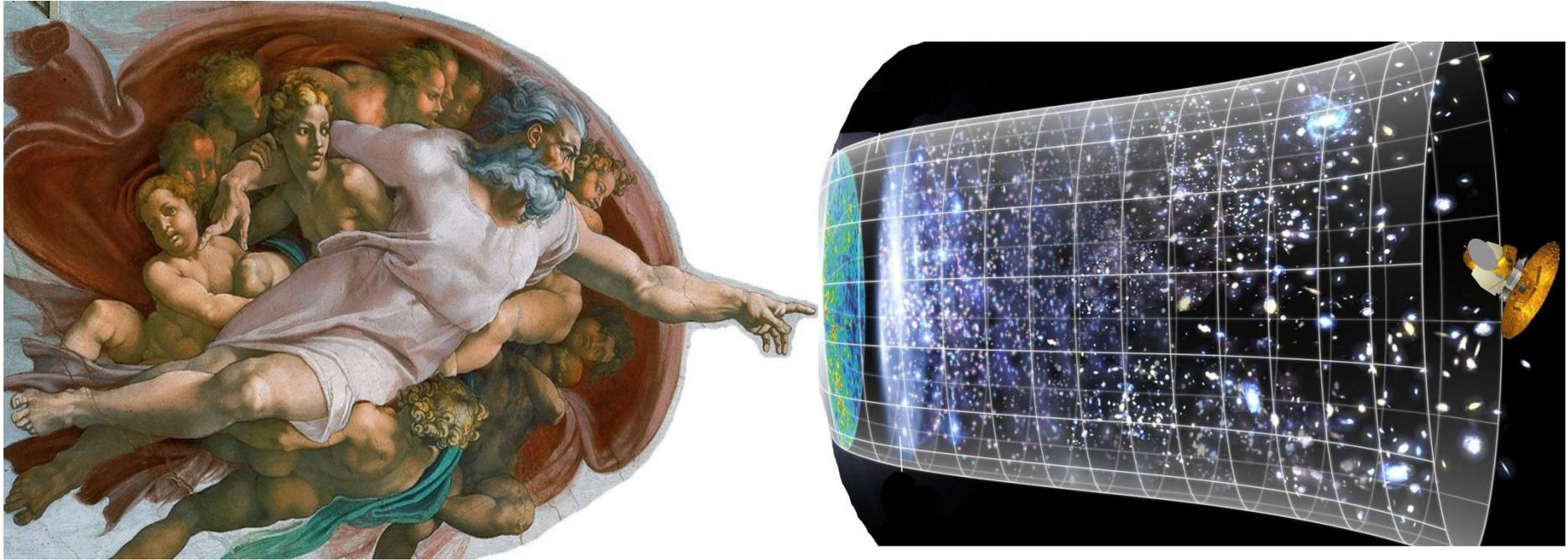
Had God a choice ?

- Einstein to his assistant Banesh Hoffmann:
**When I am judging a theory,
I ask myself whether, if I were God,
I would have arranged
the world in such a way.**
- Einstein to his assistant Ernst G. Straus:
**What really interests me is
whether God could have
created the world any differently.**

Leibniz' question
whether we live in the
'Best of all Worlds'
in physics



Had God a choice ?



What if?

Fine tuning: What if?

- nr of **dimensions** $\neq 3$?
- **cosmos not flat** ?
- **cosmological constant** not so tiny?
- matter = **antimatter** ?
- **masses: quarks**: down heavier than up ?
- no **Higgs** ?

• **electron** lighter, heavier ?

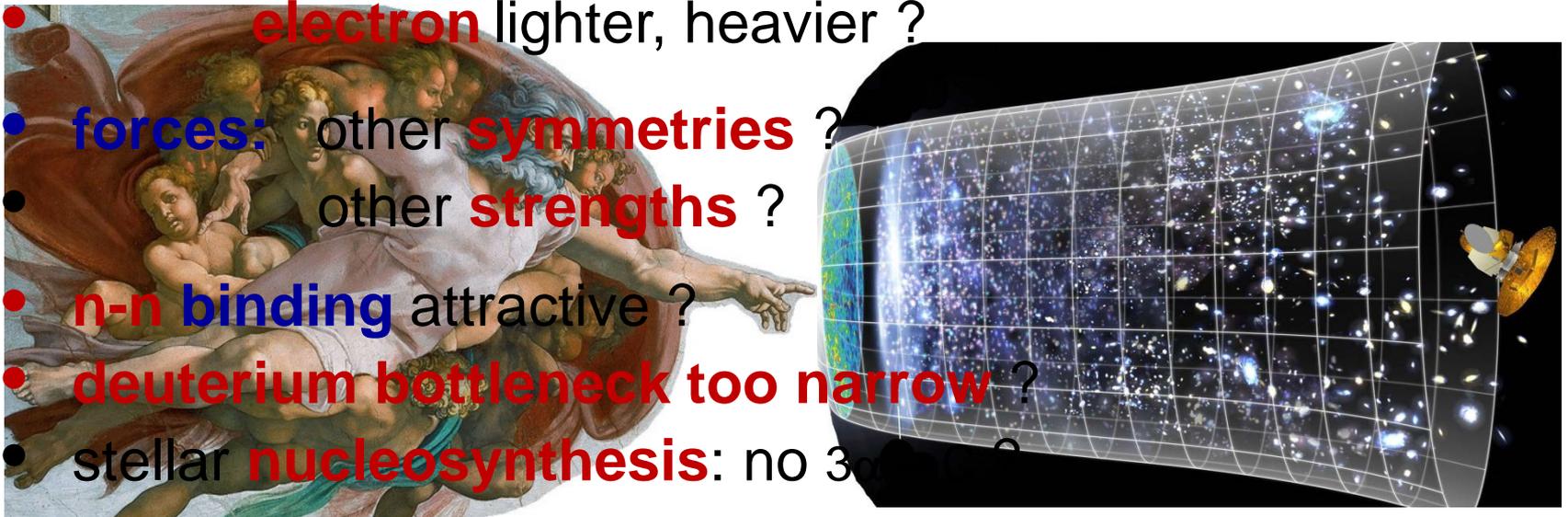
• **forces**: other **symmetries** ?

• other **strengths** ?

• **n-n binding** attractive ?

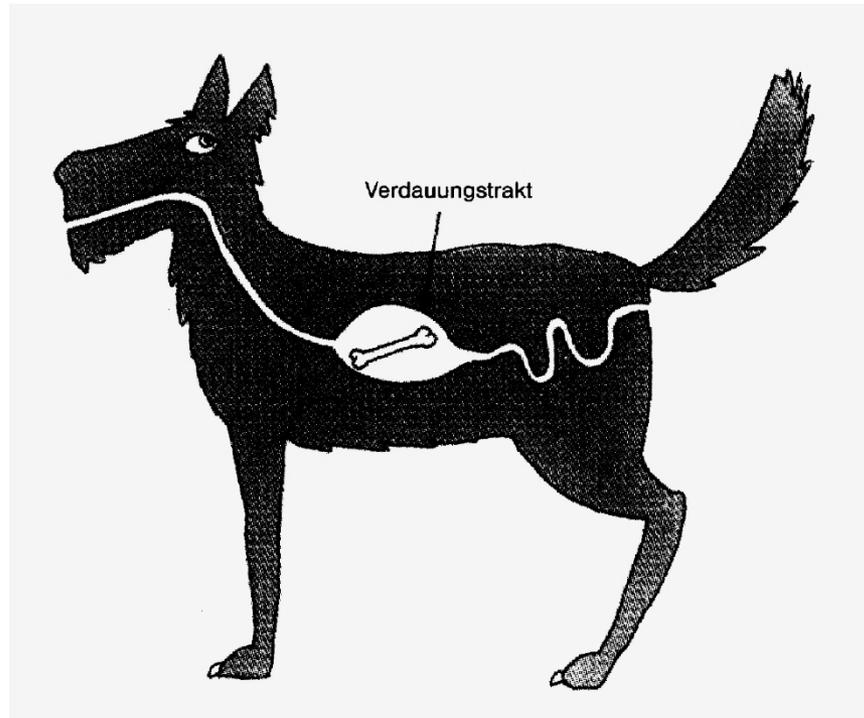
• **deuterium bottleneck too narrow** ?

• stellar **nucleosynthesis**: no 3 α ?



Dimensions

Life in 2 dimensions -
topologically not connected:
crossing nerves, blood vessels ?
digest through one-dimensional boundaries ?

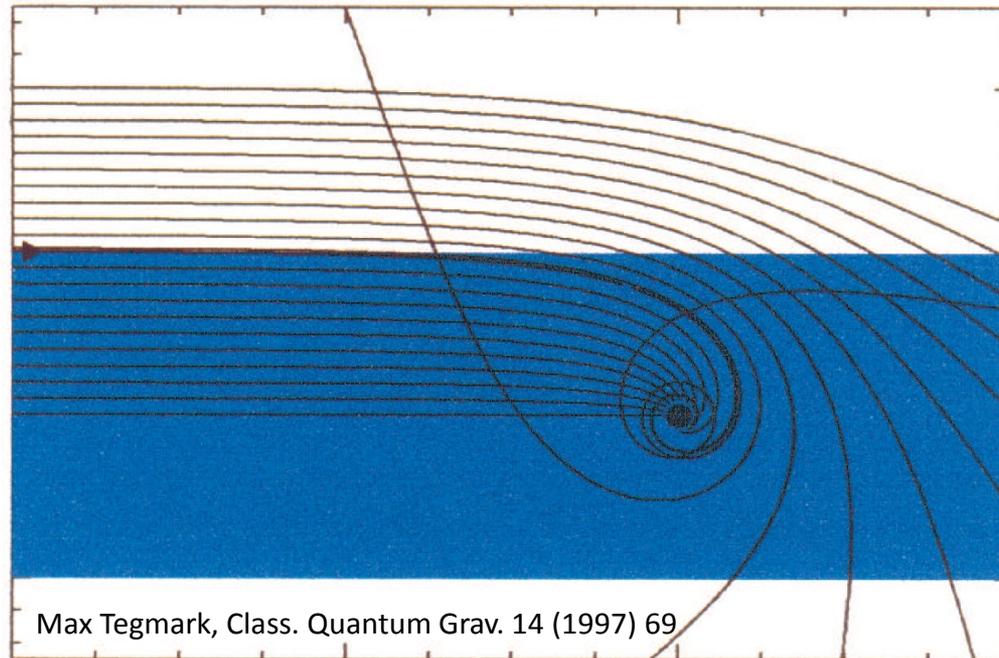


Hawking's two-dimensional dog

2 bodies in 4 dimensions

P. Ehrenfest 1917: scattering of light on heavy mass:

particle is either absorbed or escapes to infinity
no stable orbits of planets and classical atoms !

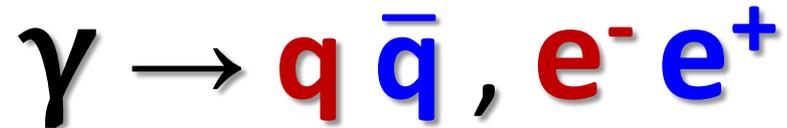


also in quantum mechanics no stable atoms !

Paul S. Ehrenfest, Proc. Royal Acad. Amsterdam 20 (1917) 200. Annalen der Physik Vol. 61 Nr. 5 (1920) 440.
F.R. Tangherlini, Nuovo Cimento 27 (1963) 636.

Matter : Antimatter

after Big Bang:



now:

$$n_b / n_\gamma \sim 10^{-9}$$

10.000.000.00**1** - 10.000.000.00**0**

Do we live from an **accident**?

$n_{\text{mat}} / n_\gamma = 0$: light only $>10^{-6}$: collapse

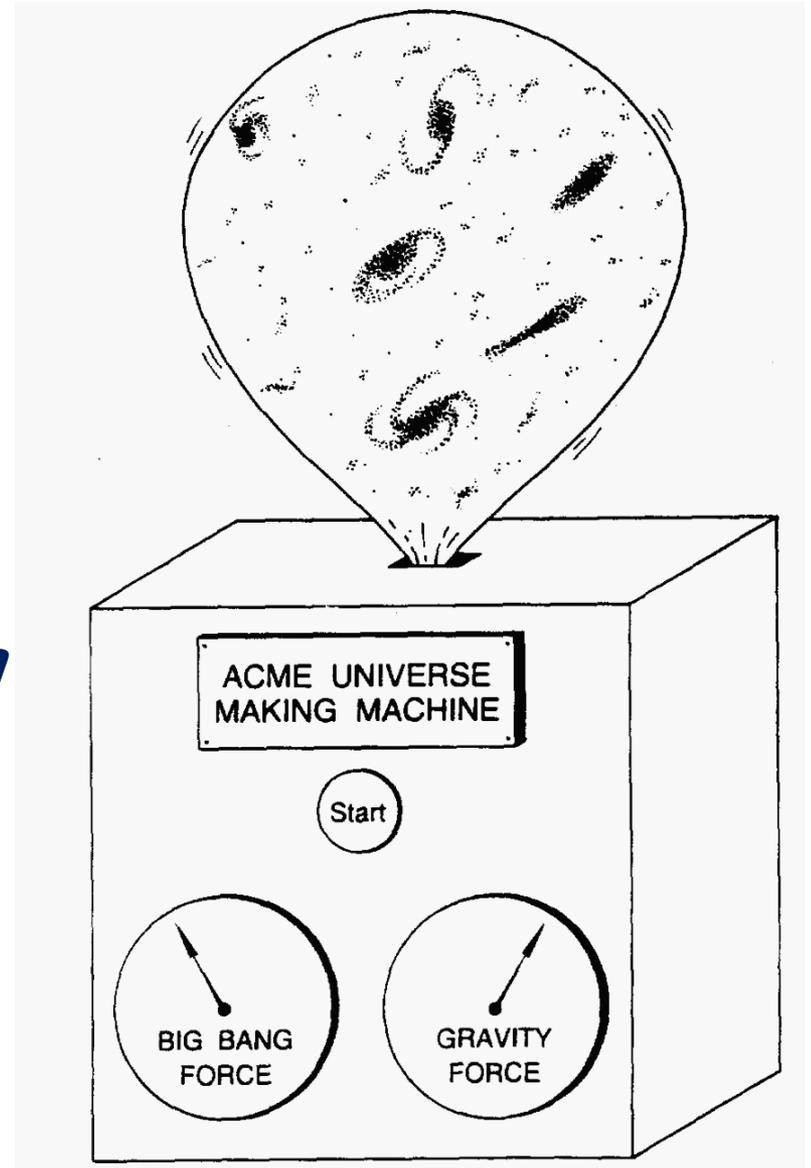
matter-antimatter asymmetry if:

- cosmos out of thermal equilibrium
- baryon number violated (proton decay)
- CP violation



Andrei Sakharov

Cosmic Inventory



Fine tuning of scalar fields

Inflation - Dark Energy - Higgs - Gravitation

• flat Universe:

$$\Omega_k = 0.001 \pm 0.006 \quad \text{Why?}$$

Dicke 1961, Weinberg 1987,
 anthropic argument on G_N , H_0 , Ω ; Λ :

too little inflation:

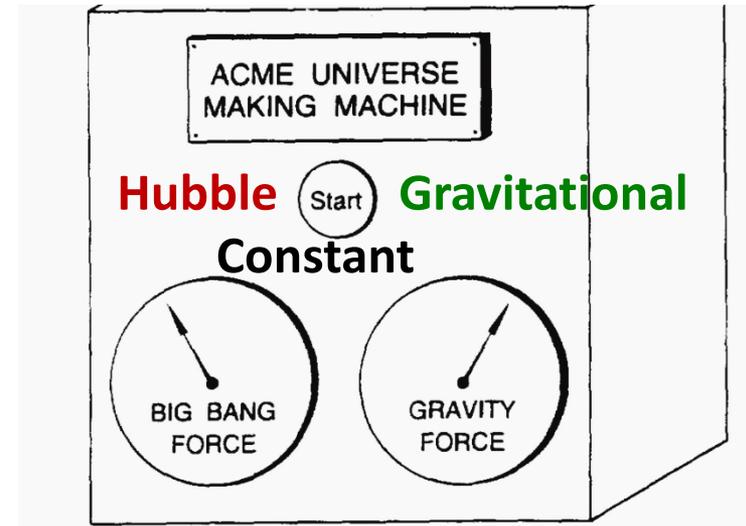
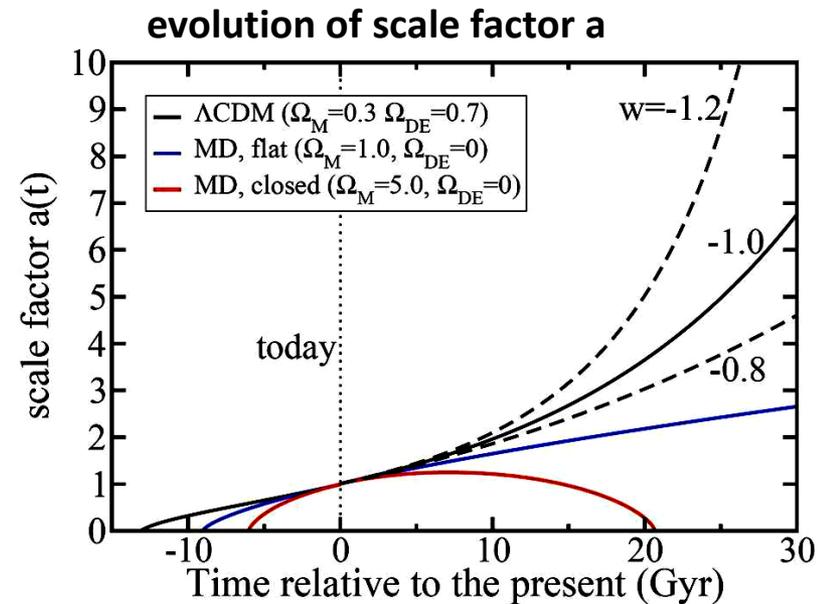
- fast recollapse, no time for life

too much inflation + Dark Energy:

- no formation of galaxies, stars + life

Fine tuning of Λ :

- to Higgs vacuum: 10^{52}
- to Planck mass: 10^{120}



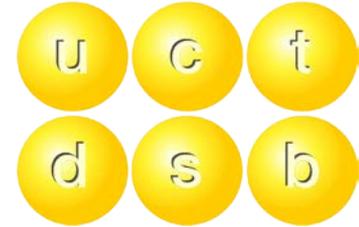
Expansion - Contraction
 Repulsion - Attraction
 Anti-Gravity - Gravity

$$\Omega = \rho / \rho_{\text{crit}} = 1$$

masses

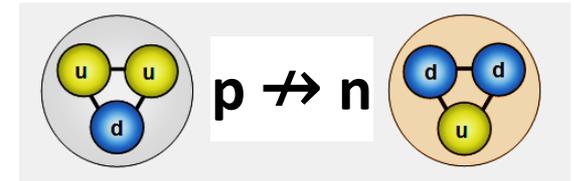
- **proton stable, neutron decays**

- $n \rightarrow p e^- \bar{\nu}_e$ since $m_n - m_p = 1.3 \text{ MeV} \approx 1\% m_{n,p}$ as
- quark mass: $m_d - m_u \approx 3-4 \text{ MeV}$



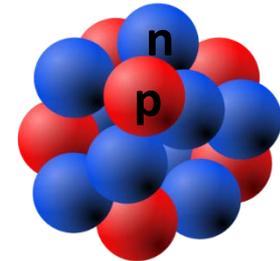
- **what if $m_u > m_d$:**

- proton decays: $p \rightarrow n e^+ \nu_e$, annihilation $e^+ e^- \rightarrow \gamma \gamma$
- deuteron unstable: $d \rightarrow 2n e^+ \nu_e$ as $m_p - (m_n + m_e) > 2.2 \text{ MeV} = E_b^d$



- **cosmos would be neutral:**

only neutrons, photons + neutrinos
no protons + electrons,
no atoms, no chemistry, no life !

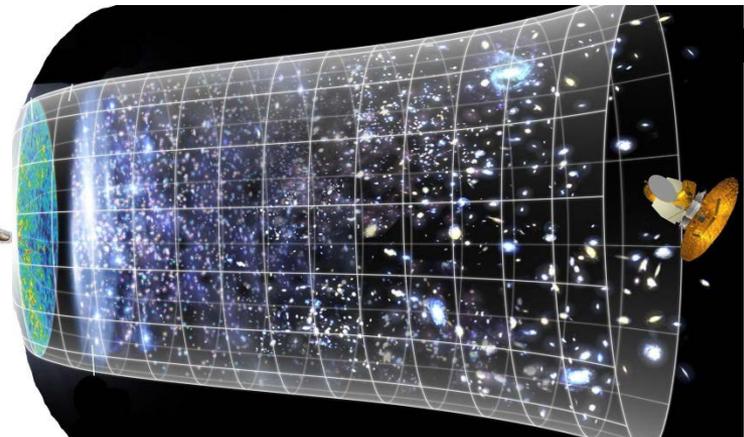


The Best of all Worlds

Einstein: **Had God a choice?**

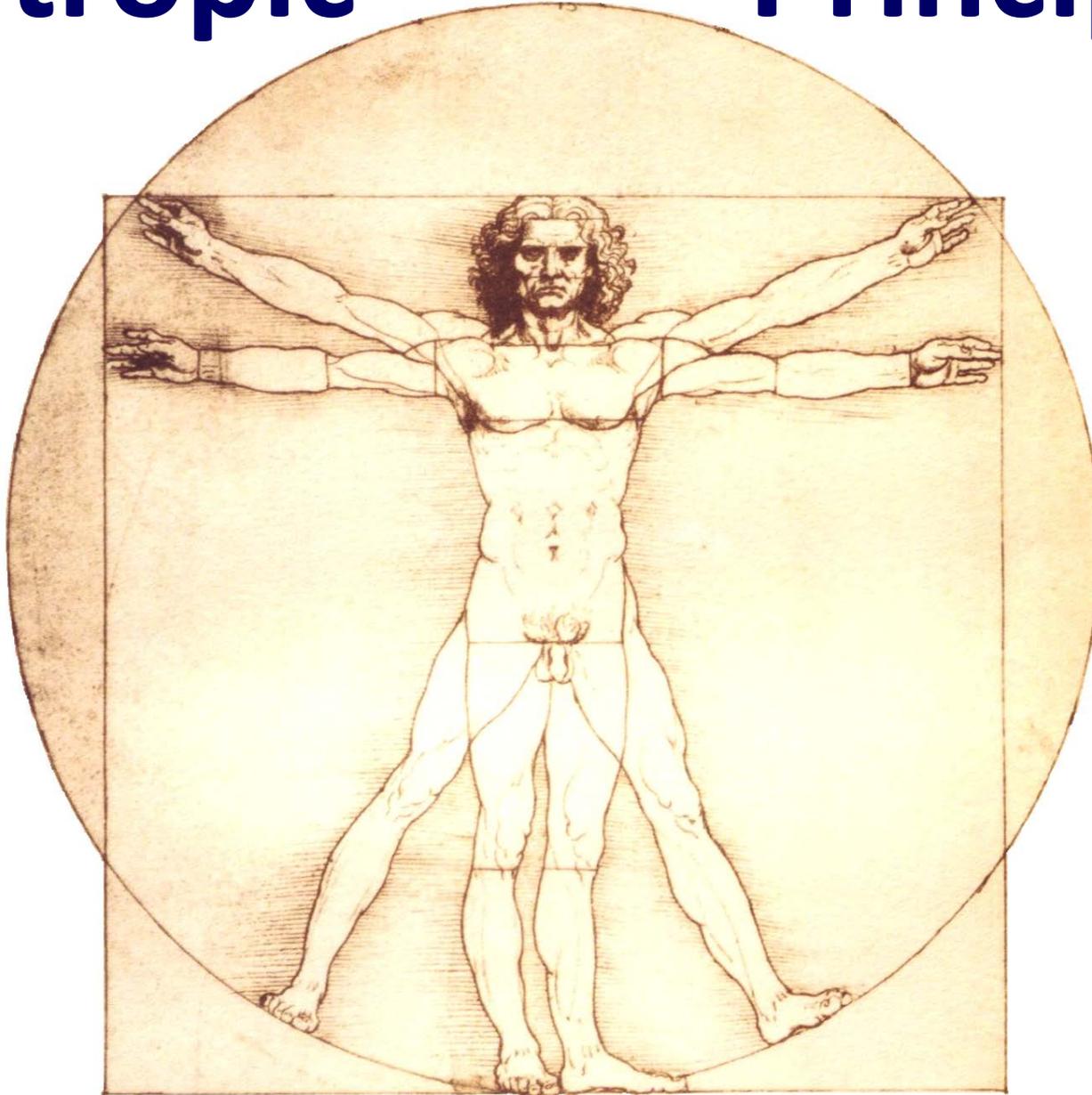
Fine tuning: **What if ?**

- | | | # |
|-------------------------------|---|---|
| • nr of dimensions | | 1 |
| • content of cosmos | $\Omega_{\text{tot}} = 1$, $\Omega_k = 0$; $\Lambda \sim 10^{-120} m_{\text{Pl}}^4$ | 2 |
| • matter- antimatter | $n_{\text{bar}}/n_{\gamma} \sim 10^{-10}$ - otherwise only light or collapse | 1 |
| • symmetries of forces | electr., weak, strong, gravity | 3 |
| • strengths of forces | G_N/α , G_F | 2 |
| • ma | | 3 |
| • nu | | 3 |



Antropic

Principle



Anthropic Principle

Steven **Weinberg**

Nobel prize 1979

A physicist talking about the anthropic principle
runs the same risk as
a cleric talking about pornography:

No matter how much you say you are against it,
some people will think
you are a little too interested.

Anthropic Principle

R. **Dicke**, Dirac's Cosmology and Mach's Principle, Nature, Nov 1961

The **existence of physicists** ... [is] sufficient to demand that ... **relations between the three** numbers [G_N , H , Ω] be satisfied.

J.D. **Barrow** and F. **Tipler**, 1986

The Anthropic Cosmological Principle

Man not only fits to the Universe.

The **Universe also fits to Man**.

S. **Hawking**, A Short History of Time, 1988

The remarkable fact is that the values of these numbers seem to have been **very finely adjusted** to make possible the development of life.

S. **Weinberg** 1987: Anthropic argument for cosmological constant

S. **Weinberg**, Living in the **Multiverse**, 2007

Applied to the **string landscape**, the Anthropic Principle "may explain **how the constants of nature that we observe can take values suitable for life without being fine-tuned by a benevolent creator.**"

Anthropic Principle: Criticism

We only have one Universe.

tautology, causal circle:

We only observe Universes that allow an observer.

no prediction: only postdiction

no science:

no repeatable experiments

fundamental parameters not derived from first principles

what is tuned:

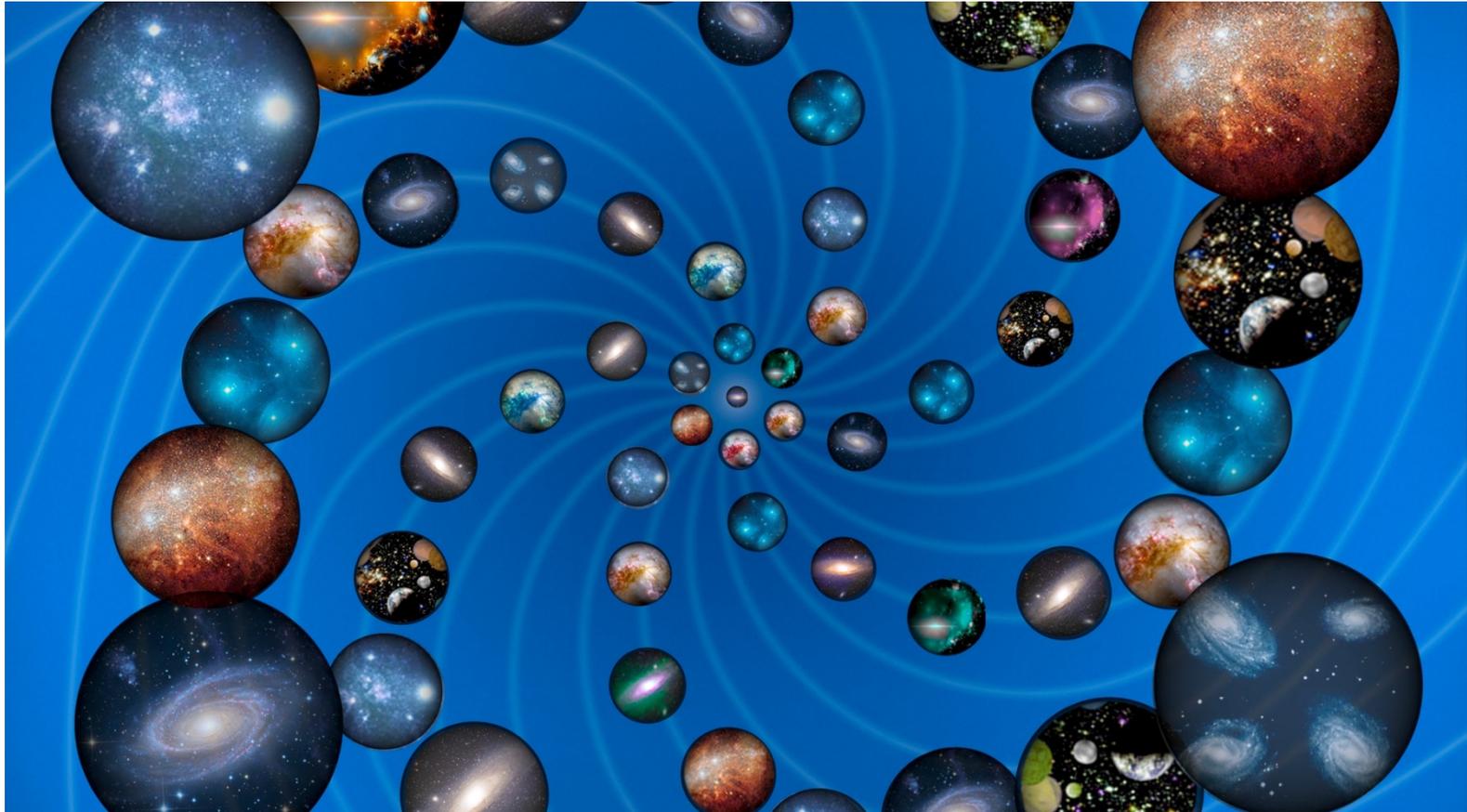
laws, fundamental and environmental parameters?

The image features a dense field of spherical objects of various sizes and colors, including shades of purple, blue, and brown. These spheres have a grainy, textured appearance, similar to planets or galaxies. The background is a dark gradient of purple and blue. The text "Universe - Multiverse" is centered in a large, white, sans-serif font.

Universe - Multiverse

Universe - Multiverse

Andrei Linde, Particle Physics and Inflationary Cosmology, 1990



Instead of a **Universe** with a single law of physics operating everywhere we are discussing an eternally existing self-reproducing **Multiverse** which consists of many different parts where **all possibilities** can be realized.

Universe - Multiverse

- **Kepler**, *Mysterium Cosmographicum* + *Harmonices Mundi*: orbits of 5 known planets behave like spheres in & around **5 Platonic Solids**

4+1 building blocks of Cosmos:

tetrahedron, octahedron, cube, icosahedron;
dodecahedron (ether, quintessence)

- two ways out of the *Mysterium* - **both** were true:

- **statistical**: more planets + planetary systems
- **fundamental**: search for underlying law - from Kepler to Newton !

- **Today**: inflation and landscape

- **statistical**: 10^{500} universes - **Multiverse**
- **fundamental**: Superstrings

- **Aristotle**: *Physica* → *Metaphysica*

- **Today**: **Universe** → **Multiverse**
Physics of our **Meta-Physics**
Best of all Worlds in a positive sense

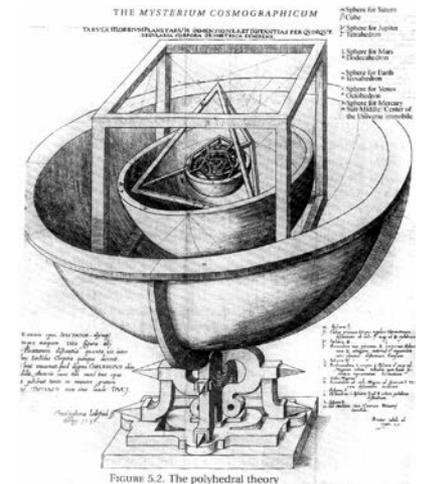


FIGURE 5.2. The polyhedral theory



Raphael: The School of Athens
Plato and Aristotle

Einstein asked

whether God had a choice
and could have made the
World any differently:

- **Fine tuning of parameters**
 - **Antropic principle**
 - **Multiverse**

100 years later still
burning questions
of physics !

